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Estimation of stature from lengths of index and ring fingers in a North-eastern Indian population

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A B S T R A C T

Forensic anthropology involves identification of human remains in a legal situation. Along with the other three parameters of forensic anthropology, i.e., age, sex and ethnicity, stature estimation is an essential element of medico-legal investigations when identifications of unknown dismembered remains are involved. The present study was conducted with an aim to find the correlation between stature and the lengths of the index and ring fingers and to derive linear and multiple regression models for estimation of adult stature from the index finger and ring finger measurements. The subjects chosen for the study were composed of adult individuals belonging to the "Rajbanshi", an ethnic community of North-eastern India. A total of 500 adults (250 males and 250 females) aged between 18 years and 60 years took part in the study. All the measurements were taken using standard techniques. Stature, index finger length and ring finger length were significantly longer in the males than the females. The correlation coefficient (r) between stature and finger lengths was observed to be positive and statistically significant. Linear and multiple regression models were derived for estimation of stature from a length of index and ring fingers. The predictive accuracy of stature estimation was higher for the females than the males. It was observed that the values of the correlation coefficient (r) and the coefficient of determination (R^2) increased in multiple regression models when compared to the linear regression models. The study also focuses on the usability of sex-specific regression models in forensic casework. The study concludes that such regression models, as those derived in the present work, can be of significant utility in the estimation of stature.

1. Introduction

Identification of human remains is an essential element in medico-legal investigations. Most of the existing methods of identification primarily employ the process of comparison with accessible records. The osteological and/or dental examination can be used to determine the characteristic features of unidentified individuals that can serve as evidence in cases of putative identification.[1] Besides details on examination of human remains,[2–5] several studies have been undertaken for estimations of sex[6–12] and age[13–16] relating to forensic and medico-legal purposes. The methodologies discussed in the studies relating to sex and age estimation typically include identification by assessment of the deceased age and sex in forensic examinations. Identifying dismembered or incomplete skeletal remains is a challenge, and the present study aims to explore how the index and ring finger lengths can be used to estimate stature.

Age and sex along with stature constitute the important criteria for establishing the identity of the remains of the human body.[17] This is because every human body part has a more or less constant relationship with stature.[18] An individual hand or foot when recovered and brought for forensic or medico-legal examination

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can provide valuable information about a person's identity.[19] A need for population specific studies on stature estimations has long been emphasized, primarily owing to the racial and ethnic variations present in different regions of the world.[20] As a result, several studies have been initiated to obtain regression models for predicting stature from body dimensions among different populations.[6,8,21–31]

Contemporary India is composed of a sizable number of ethnic and indigenous populations having enormous amounts of ethnic and genetic diversity.[32,33] The country has the largest number of indigenous people in the world and that includes diverse tribal, non-tribal and caste populations. India is also a vast country with varied geographical conditions and stature is observed to vary with ethnicity, sex and geographical locations.[33] There exists a need for developing regression models for the estimation of stature from different body parts in various ethnic and population groups. A number of studies have been undertaken in this regard.[17,19,34–39]

The applicability of regression models derived from hand dimensions in earlier studies such as that of Bhatnagar et al.[34] is limited in scenarios where a part of the hand is brought for examination. Thus, there is a need to derive regression models for stature estimation using a part of the hand. Stature estimation of middle finger length has been reported by Rastogi et al.[17] This study[17] reported a positive and significant correlation between stature and middle finger length and proposed that similar studies should be undertaken on stature estimation from other fingers among different populations. The forensic importance of this study is that the regression models derived in the study can be applied in cases where stature estimations are needed in the absence of other bones typically used to estimate stature, such as the long bones.[20,22]

Studies on stature estimation among the populations of northern part of the state of West Bengal in India are practically non-existent. The area is the home to a number of indigenous caste, tribal and non-tribal ethnic populations such as the Rabha, Meche, Toto, Dhimal, Rajbanshi, Bengali Caste and Bengalee Muslim. The present study has been conducted among individuals of the Rajbanshi population. A detailed literature search has shown that such forensic studies are scarce among this population and there are only two studies in this regard.[41,42]

2. Material and methods

2.1. Subjects

The data for the present study were obtained from 500 adult Rajbanshi individuals (males: 250; females: 250) aged between 18 and 60 years. The individuals were residents of a Rajbanshi-dominated village named 'Kachuaboalmari' located in Nandanpur Gram Panchayet, Sadar Block, Police station Kotwali, District Jalpaiguri of the state West Bengal, in India. Initially, a total of 528 Rajbanshi individuals was randomly selected and approached for the study. All the individuals were free from any physical deformity and the subjects were also interviewed for information regarding any previous physical injury and/or operation, or any other trauma to the index and ring fingers of either hand. The nature of the study was explained to them in detail. Of them, 28 individuals (5.30%) declined to participate in the study. Informed consent was taken from the subjects who participated in the study. The study has been conducted in accordance with the ethical standards of human experiments laid down in the Helsinki Declaration of 2000.[43] The necessary ethical permission and clearances were obtained from the ethical committee of Department of Anthropology, University of North Bengal. All the necessary field permissions were taken from the Nandanpur Gram Panchayet (a local village level governing authority) and Sadar block level authority of Jalpaiguri district prior to the conduct of the study. The data were collected during the period from January 2010 to June 2010.

The age of the individuals was recorded and verified from the age certificates and other documents (ration and voter identification cards) issued by the competent authorities. The individuals were identified as Rajbanshis by observing their physical features, cultural features and by recording their surnames. These were subsequently verified from the official records of the Gram Panchayet. All the individuals included in the present study were engaged in agriculture, thereby negating the effects of physical activity and nutritional status on stature to a large extent.

The Rajbanshis are chiefly distributed in the North-eastern part of India, Assam and few districts of North Bengal.[44] It is generally agreed that ethnically the Rajbanshi show resemblances with the Koch population of the neighboring state of Assam and it is being conjectured that they belong to a mixed ethnic ethnicity of Austroasian/Dravidian and Mongolian.[44,45] It is opined that Rajbanshis belonged to Dravidian stock that came in contact with the heterogeneous Mongoloid populations.[46,47] A recent study on genetic markers among the populations of North-eastern India reported that the Rajbanshi was a semi-Hinduized caste group located in between the clusters of Caucasoid caste and Mongoloid tribal populations.[48]

2.2. Anthropometric measurements

Five anthropometric measurements were recorded from the subjects following the standard anthropometric procedures of Singh and Bhasin.[49] The measurements are as follows:

a) Stature/Height vertex
b) Length of index finger of left hand (LIF)
c) Length of ring finger of left hand (LRF)
d) Length of index finger of right hand (RIF)
e) Length of ring finger of right hand (RRF)

Stature is the vertical distance from vertex to the floor with the head of the subject held in the Frankfurt Horizontal plane. It was measured with the help of an anthropometer rod (Galaxy Scientific, New Delhi, India) having a precision of 0.1 cm. The subjects were barefooted at the time of recording the measurement. Owing to the diurnal variation in stature[50] the individuals were measured during the morning hours prior to leaving for their work. The length of the index and ring fingers were measured as the linear distance between the midpoint of the proximal-most flexion crease of the base, and the anterior-most points (tip) of the index and ring finger respectively in the midline on the palmar surface. A sliding caliper (Galaxy Scientific, New Delhi, India) with precision of 0.1 cm was utilized to determine the length of index finger of left hand (LIF), length of ring finger of left hand (LRF), length of the index finger of right hand (RIF) and length of ring finger of right hand (RRF). All the anthropometric measurements were recorded to the nearest to 0.1 cm.

All the anthropometric measurements for the present study were taken by one observer (AG). The technical errors of measurement {TEM $= \surd(\sum D^2/2N)$, D = difference between the measurements, N = number of individuals measured} which is an accuracy index and measures the standard deviation between repeated measures[51,52] have been determined to check the consistency of the measurements. Even though a number of methods of measuring inconsistency are available, the preferred method involves calculation of relative TEM and subsequent determination of the coefficient of reliability [$R = \{1 - (\mathrm{TEM})^2/\mathrm{SD}^2\}$, SD = standard deviation of all measurements].[51,52] The TEM were calculated from

measurements taken on 30 randomly selected Rajbanshi individuals (males: 15; females: 15) by two of the authors, NM and AG. The measurements were taken twice on each individual by them. The results of the intra-observer and inter-observer TEM analysis are shown in Table 1. Very high values of TEM (>0.97) were obtained in both intra- and inter- observer analysis of height, LIF, LRF, RIF and RRF. The TEM values were observed to be within the acceptable limits ($R = 0.95$) as suggested by Ulijaszek and Kerr.[52] Thus, the measurements taken by AG were considered to be reliable and reproducible and TEM values were not considered for further statistical consideration.

2.3. Statistical analysis

The statistical analysis was done using SPSS (Statistical Package for Social Sciences, version 15.0) computer software (SPSS, Inc., Chicago, IL, USA). The data obtained were statistically analyzed for correlation, regression, paired *t*-test and one-way analysis of variance (ANOVA). The MS-Excel-2007 program (Microsoft) was utilized to calculate the intra- and inter- observer TEM of the anthropometric measurements. The descriptive analysis was done to obtain mean, standard deviation and range of the measurements. ANOVA and students *t*-test were utilized to analyze the differences in stature, LIF, LRF, RIF and RRF between the male and the female individuals. The paired *t*-test was utilized to assess the differences in the length of index finger (IF) and ring finger (RF). Pearson's correlation was performed to determine the relationship between stature, LIF, LRF, RIF and RRF. Linear regression models were derived to individually estimate stature from LIF, LRF, RIF and RRF. Stepwise multiple regression models were derived to estimate stature from a combination of IF, RF and age as co-variables. Linear and multiple regression models were derived independently for the males and the females (sex-specific regression models) and for the pooled data ($n = 500$) where the sex was presumed as unknown. A *p*-value of less than 0.05 was considered to be statistically significant.

3. Results

The mean, standard deviation and range of stature, LIF, LRF, RIF and RRF among the Rajbanshi males and females in the present study are shown in Table 2. The Rajbanshi males exhibited a mean stature of 160.15 cm. The mean LRF (7.14 cm) was greater than the LIF (6.86 cm) and the mean RRF (7.05 cm) was greater than the RIF (6.84 cm). The Rajbanshi females had a mean stature of 148.54 cm. The mean LRF (6.61 cm) was greater than the LIF (6.37 cm) and the mean RRF (6.58 cm) was greater than the RIF (6.39 cm). Almost identical standard deviations were obtained for the LIF, LRF, RIF and RRF among the subjects. It is evident that stature and finger lengths were significantly longer among the males when compared with the females ($p < 0.001$). With regard to the bilateral difference (left vs. right asymmetry) in the finger length measurements, it was observed that the differences between the right and left hands were statistically significant for IF and RF lengths for the female individuals ($p < 0.01$). Among the male individuals, left and right differences were significant only for RF (Table 3).

When the percentages of finger length and stature were considered, it was observed that among the males, LIF varied between 3.56% and 5.06% of stature, LRF varied between 3.62% and 5.31% of stature, RIF varied between 3.68% and 5.00% of stature, and the RRF varied between 3.50% and 5.12% of stature. When the female individuals were considered, LIF varied between 3.37% and 5.12% of stature, LRF varied between 3.64% and 5.39% of stature, RIF varied between 3.37% and 5.12% of stature, and the RRF varied between 3.64% and 5.25% of stature.

The correlation coefficients (r) between stature and finger lengths were observed to be positive and statistically significant. Among the males, the correlation coefficients between stature and LIF, and stature and LRF were 0.563 ($p < 0.001$) and 0.547 ($p < 0.001$) respectively. In the case of stature and RIF, the correlation coefficient was 0.577 ($p < 0.001$), while for stature and RRF it was 0.563 ($p < 0.001$). Among the females, the correlation coefficient between stature and LIF, and stature and LRF was 0.656 ($p < 0.001$) and 0.650 ($p < 0.001$) respectively. In the case of stature and RIF ($r = 0.645$) and stature and RRF ($r = 0.633$) among the females, the r value was statistically significant ($p < 0.001$). When all the subjects were taken together (males and females), stature was observed to be significantly and positively correlated with LIF ($r = 0.731$, $p < 0.01$), LRF ($r = 0.721$, $p < 0.01$), RIF ($r = 0.718$, $p < 0.01$) and RRF ($r = 0.711$, $p < 0.01$).

3.1. Linear regression models for stature estimation

Linear regression analysis was done to estimate stature from the index and ring finger length in both hands. Stature was taken as the dependent variable and LIF, LRF, RIF, RRF as the independent variables. The regression equations derived for the estimation of stature from LIF, LRF, RIF and RRF among the Rajbanshi male and female individuals are shown in Table 4. In all the cases, the regression coefficients were observed to be statistically significant ($p < 0.05$). The predictive accuracy of stature estimation was found to be higher among the females than the males. When the regression models were derived for the estimation of stature in all the subjects together irrespective of the sex of subjects, the predictive accuracy of stature estimation was higher than that reported for males and females individually (Table 4). The Standard Error of Estimate (SEE) was the least for the linear regression models derived from the females followed by the males and the pooled data.

Table 1
Technical errors of measurement of the anthropometric measurements.

Variables	Intra-observer		Inter-observer	
	TEM	Coefficient of reliability (R)	TEM	Coefficient of reliability (R)
Stature	0.061	0.99	0.069	0.99
LIF	0.058	0.97	0.057	0.97
LRF	0.055	0.98	0.052	0.98
RIF	0.059	0.98	0.050	0.98
RRF	0.066	0.96	0.053	0.98

Table 2
Descriptive statistics: Stature, LIF, LRF, RIF and RRF (in cm) and age (year) among the Rajbanshi individuals.

Variable	Males ($N = 250$)			Females ($N = 250$)		
	Mean	S.D.	Range	Mean	S.D.	Range
Stature (cm)	160.15	6.37	144.0–176.9	148.54	5.80	130.7–163.5
LIF (cm)	6.86	0.40	5.70–8.10	6.37	0.41	5.00–7.60
LRF (cm)	7.14	0.44	5.80–8.50	6.61	0.46	5.40–8.00
RIF(cm)	6.84	0.41	5.90–8.00	6.39	0.41	5.00–7.60
RRF(cm)	7.05	0.43	5.60–8.20	6.58	0.42	5.40–7.80
Age (year)	41.63	11.60	18.0–60.0	37.67	11.49	18.0–60.0

Table 3
Bilateral differences (right vs.left) in the lengths of IF and RF (in cm) among the Rajbanshi individuals.

Variables	Male		Female	
	t – Value	p – Value	t – Value	p – Value
IF (cm)	0.992	0.322	2.374	0.018
RF (cm)	7.781	0.000	2.636	0.009

Table 4
Linear regression equation in stature (in cm) estimation from LIF, LRF, RIF and RRF (in cm) among the Rajbanshi individuals.

Sex	Variables	Regression equation	SEE (cm)	R	R^2
Male ($n = 250$)	LIF	99.473 + 8.850 (LIF)	5.273	0.563	0.317
	LRF	103.631 + 7.917 (LRF)	5.337	0.547	0.300
	RIF	99.200 + 8.905 (RIF)	5.209	0.577	0.333
	RRF	101.602 + 8.303 (RRF)	5.269	0.563	0.318
Female ($n = 250$)	LIF	89.344 + 9.294 (LIF)	4.386	0.656	0.430
	LRF	94.234 + 8.214 (LRF)	4.413	0.650	0.423
	RIF	90.545 + 9.072 (RIF)	4.440	0.645	0.416
	RRF	91.426 + 8.678 (RRF)	4.497	0.633	0.401
Unknown ($n = 500$)	LIF	68.514 + 12.979 (LIF)	5.742	0.731	0.535
	LRF	74.249 + 11.650 (LRF)	5.830	0.721	0.520
	RIF	69.239 + 12.859 (RIF)	5.860	0.718	0.516
	RRF	70.770 + 12.261 (RRF)	5.924	0.711	0.505

Table 5
Stepwise multiple regression equation in statute (in cm) estimation from the lengths of IF and RF (in cm) among the Rajbanshi individuals.

Sex	Variables	Equations	SEE (cm)	R	R^2
Male	LIF, LRF	97.129 + 5.573(LIF) + 3.476(LRF)	5.228	0.575	0.331
($N = 250$)	RIF, RRF	96.412 + 5.533(RIF) + 3.669(RRF)	5.164	0.589	0.347
Female	LIF, LRF	87.753 + 5.246(LIF) + 4.141(LRF)	4.294	0.675	0.456
($N = 250$)	RIF, RRF	86.814 + 5.434(RIF) + 4.101(RRF)	4.362	0.662	0.438
Unknown	LIF, LRF	66.851 + 7.673(LIF) + 5.346(LRF)	5.622	0.745	0.555
($N = 500$)	RIF, RRF	65.575 + 7.404(RIF) + 5.834(RRF)	5.734	0.733	0.537

3.2. *Stepwise multiple regression models for stature estimation*

Stepwise multiple regression equations derived for stature estimation from both IF and RF among the Rajbanshi individuals is shown in Table 5. The regression coefficients were statistically significant ($p < 0.05$) for the multiple regression models derived from the right and left hands. Compared to the linear regression models, the values of the correlation coefficient (R) and the coefficient of determination (R^2) increased when both IF and RF were taken together.

The next table (Table 6) depicts the step-wise multiple regression equations derived for stature estimation based on the IF, RF and the age of the Rajbanshi individuals as co-variables. The regression coefficients were statistically significant ($p < 0.05$). It was also observed that the values of the correlation coefficient (R) and the coefficient of determination (R^2) increased more when age was considered along with IF and RF.

The predictive accuracy of stature estimation was found to be higher among the females than the males. When the regression models were derived for the estimation of stature in all the subjects together irrespective of the sex of subjects, the predictive accuracy of stature estimation was observed to be higher than that reported for the males and the females individually (Tables 5and 6). The standard error of estimate (SEE) was the least for multiple regression models derived from the females followed by the males and the pooled sample. The SEE was marginally lower for the multiple regression models when compared with the linear regression models.

4. Discussion

A detailed literature search in "Pubmed" and the "Science Citation Index" found a limited number of studies on the stature estimation from finger lengths. Jasuja and Singh[53] reported the stature estimation from the hand and the phalange lengths among North Indian populations. Rastogi et al.[17] tried to establish the stature of an individual using the length of the middle finger length among 500 students studying in Manipal. Habib and Kamal[54] have examined the relationship between stature and hand and phalangeal lengths among Egyptian individuals.

Stature among the male Rajbanshis was significantly longer than the females, similar to the observations in the earlier studies involving them.[41,42] In the present study, IF and RF lengths were significantly longer in the male Rajbanshi individuals than their female counterparts. Sex differences in the absolute length of fingers among humans have been demonstrated recently, with the male fingers being longer than females.[40,55] The length of the RF has been observed to be longer as compared with the length of the IF and it is in conformity with the results reported by Rastogi et al.,[17] Kanchan and Kumar[40] and Krishan et al.[55] The results of the present study further lend credence to the fact that there is an existence of the left and right variations in RF and IF among humans. The left and right variations in these anthropometric variables have also been reported by Rastogi et al.,[17] Kanchan and Kumar[40] and Krishan et al.[55] Studies on the estimation of stature from hand and phalangeal measurements have also shown a positive correlation with between stature and hand and phalangeal measurements.[53,54] As the present study shows a significant and positive correlation between stature and finger lengths (LIF, LRF, RIF and RRF), it may be surmised that stature displays a biological correlation with finger lengths of the individuals. Thus, it may be predicted that stature can be successfully estimated from IF and RF lengths. The correlation coefficient between stature and length of IF is similar to that observed between stature and length of the RF. The present study indicates that IF and RF can provide reliability and accuracy in estimating stature of an unknown individual.

Stature can be estimated from each finger (IF and RF) using linear and stepwise multiple regression models. Since IF and RF have not been utilized in the estimation of stature in any earlier studies, the findings of our study cannot be compared per se. When compared with the linear regression models derived from the middle finger length in a recent study,[17] it is evident that the correlation coefficient (R) and the coefficient of determination (R^2) derived for the IF and RF lengths in this study is comparable and marginally higher than that of the middle finger length. The predictability of regression models in stature estimation increased when multiple regressions were performed, more so when age was added as another co-variable. It was further observed that the values of R and R^2 increased as the effects of both IF and RF came into force. For the pooled data, when the sex was presumed to be

Table 6
Stepwise multiple regression models in statute (cm) estimation from the lengths of IF and RF (in cm) after adding age (year) as a co-variable among the Rajbanshi individuals.

Sex	Side	Equations	SEE (cm)	R	R^2
Male ($N = 250$)	Left	102.668 + 5.100(LIF) + 3.664(LRF) − 0.08740(AGE)	5.139	0.597	0.356
	Right	101.855 + 5.594(RIF) + 3.364(RRF) − 0.08920(AGE)	5.070	0.611	0.373
Female ($N = 250$)	Left	90.651 + 4.958(LIF) + 4.374(LRF) − 0.06930(AGE)	4.228	0.689	0.475
	Right	89.566 + 5.049(RIF) + 4.470(RRF) − 0.07230(AGE)	4.291	0.677	0.459
Unknown ($N = 500$)	Left	67.910 + 7.573(LIF) + 5.465(LRF) − 0.03070(AGE)	5.617	0.746	0.557
	Right	66.585 + 7.366(RIF) + 5.899(RRF) − 0.03050(AGE)	5.728	0.734	0.539

unknown, the values of R and R^2 remained appreciably high. A similar observation was made by Kanchan et al.[38] who reported that stature can be estimated accurately by regression analysis even when the sex remains unknown. Higher R and R^2 values in the pooled data may be attributed to a relatively large sample size ($N = 500$) on which the statistical analysis was performed as compared to the sex-specific regression models for males and females independently ($N = 250$ each).

The accuracy and utility of regression models in forensic examinations are based on SEE. The SEE was least for the regression models derived for the females followed by the males and the pooled data (Tables 4–6). Our findings suggest that stature can be estimated with greater precision among the females than the males. Similar observations are made by Rastogi et al.[17] in their observations on the stature estimation from middle finger lengths. Though the stature can be estimated from IF and RF even when the sex remains unknown, the precision of the linear and multiple regression models for pooled data was lower when compared to the sex-specific regression models derived in the present study (Tables 4–6). This indicates the need and preference for sex-specific regression models in forensic casework.

In the present study, adult individuals ranging in age from 18 to 60 years were taken. Stature is usually a straight forward parameter to establish among adults However, it is complicated due to the fact that the adult stature declines significantly with advancement in age after attaining adulthood.[56] On an average, the adult stature of an individual is attained up to 18 years of age, with very little increments after that.[57] It has been reported that after the age of 25 year, for every 25 years, stature is shortened by about 2.5 cm.[58] Some authors are of the opinion that this kind of stature loss starts at the age of 40 years and thereafter, there is a relatively rapid decrease in stature.[56] Future studies should take into account the effect, if any, of stature diminishment in older individuals when developing standards to estimate stature for unknown individuals based on index and ring finger lengths.

5. Conclusions

Estimation of stature from IF and RF measurements can be a useful approach when part of a hand with intact fingers is brought for examination in cases when other more reliable samples like long bones or other body parts are not available for forensic and medico-legal examination. The present study is the first study to evaluate stature from the lengths of IF and RF from an indigenous ethnic adult population of India. The study reports the existence of the sex differences between the male and the female individuals with respect to IF and RF. The study reports a positive and statistically significant correlation between stature, IF and RF. The study has been successful in estimating stature from the LIF, LRF, RIF and RRF among adult Rajbanshi male and female individuals using linear and multiple regression analysis. The predictive accuracy of multiple regression models is more than that of linear regression models.

The present study is an important one among the widely distributed Rajbanshi population of North Bengal in the eastern part of India. The study concludes that it is possible to estimate stature from LIF, LRF, RIF and RRF using sex-specific regression models as well as using regression models independent of sex in cases when the sex of the individual remains unknown, with reasonable accuracy. The results also indicate the significance of the usability of sex-specific regression models in forensic casework. The significance of the present study primarily lies in the simplicity of procedure/measurements, and its applicability and accuracy in the prediction of stature when a part of the hand is brought for examination.

Ethical approval

Department of Anthropology, University of North Bengal.

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None.

Conflict of interest

The authors declare that there is no conflict regarding this research and manuscript.

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